RAIL TRANSPORT OF PERISHABLE COMMODITIES IN EUROPE

ARS-NE-96
1978

AGRICULTURAL RESEARCH SERVICE • U.S. DEPARTMENT OF AGRICULTURE

PREFACE

The research reported here is part of a broad program of research by the Agricultural Research Service on the problems of shipping U.S. agricultural products to overseas markets. Specifically, this report was prepared to provide information to exporters of U.S. perishable commodities on the capabilities of the European railroads that might be used to move their products from port areas to inland markets throughout Europe.

The cooperation and assistance of the following organizations are gratefully acknowledged: United Fruit Continental Corporation, Rotterdam, The Netherlands, for supplying the product and making the railcars available; Muller-Thompson, Rotterdam, The Netherlands, the stevedoring agent; Migros Co-operatives, Zurich; Coop Switzerland, Basel; and Banfi, Locarno, Switzerland, for receiving the shipments. Special credit is due Interfrigo, Basel, Switzerland, for supplying information about their organization and equipment.

The research was conducted under the general supervision of Philip L. Breakiron, Transportation and Packaging Research Laboratory, Beltsville, Maryland.

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SUMMARY

The transport of products under controlled temperatures in railcars in most European countries is administrated by one organization called Interfrigo. This organization and its affiliated members offer noninsulated-ventilated and insulated ice bunkers and mechanically refrigerated railcars and van containers for transport of agricultural products within Europe. The supply of mechanically refrigerated railcars and van containers is limited. The transport by rail of fresh fruit and vegetables in Europe is generally in ice bunker railcars, which are either noninsulated-ventilated or insulated.

The performance of the insulated ice bunker railcar was studied as a possible method of moving U.S. perishable commodities from ports to inland points in Europe.

As U.S. perishable commodities are not currently moved by this system, bananas, which are transported by this system, were selected for purposes of this study as a commodity requiring strict temperature control during transit. The transport of bananas was evaluated during different seasons of the year with water ice in the ice bunker for a summer shipment, a gas heater on top of load for a winter shipment, and air circulation only during a fall-spring shipment. The average product temperature increased from the time of loading to unloading from a range of 13.9-14.4 to that of 15.0-16.7°C.

Generally, there was little difference in product temperatures between locations in the loads except for top-layer positions during the winter shipment. There a gas heater placed on top of the load caused the product temperature of bananas to increase about 2°C (3°F) more than bottom layers.

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INTRODUCTION

Recent improvements in ocean transport, including containerization and faster ships, have resulted in shorter Atlantic transit periods (5 to 7 days) and increased service from many east coast and Gulf ports; improved refrigeration systems on van containers for maintaining desirable transit temperatures have also helped to increase the accessibility of European markets to shippers of U.S. perishable products. With these improved services available to U.S. shippers, the list of U.S. perishable commodities available for export now can include many which in the past could not survive the 10- to 20-day ocean transit period. The movement of these products from the European port areas to inland market centers also must be rapid, and the vehicles used should have the capability of maintaining desired transit temperatures in order to protect the quality and shelf life of the products.

The potential to expand the exports of U.S. perishable commodities should increase with the availability of improved transit and service from production points to consumption points. In the 1975-76 shipping season, U.S. fresh fruit and vegetable exports totaled about $612 million, with about $79.5 million in exports to the enlarged European Economic Community. 2/

This report is one of a series designed to acquaint U.S. exporters with the availability and capabilities of transport systems for the movement of perishable commodities within Europe.

Most U.S. commodities are transported by break-bulk or in van containers. Transit from the port areas to inland destinations can be by truck, barge, or rail. Presently the majority of the fresh fruits and vegetables is transported to inland destinations by truck.

The fuel crisis has hit the transportation industry in Europe just as hard as in the United States. Increased fuel costs, limitations in fuel availability, restrictions in speed limits, and changes in laws governing the amount of time truckdrivers can drive have doubled the cost of transporting commodities by truck within Europe in the last 3 years in addition to increasing transit time. This increase in cost of truck transport may lead shippers and receivers to look for alternative transport methods in order to be competitive.

One of the alternative transport methods for moving U.S. agricultural products within Europe may be by rail. A review of the literature has not shown any published data on the capabilities of European rail equipment to maintain desired transit temperatures; however, there are some unpublished data. The most common European railcar which can maintain desired transit temperatures is the insulated ice bunker railcar. Therefore this railcar was selected for study in this report.

2/ Foreign Agricultural Trade of the United States, Economic Research Service, U.S. Department of Agriculture, November 1976, pp. 6 and 51.

The objectives of this study were: (1) to identify and describe the network of European railroads available for movement of U.S. perishable commodities within Europe; (2) to identify the types of equipment available for transporting perishable commodities; and (3) to report the results of several test shipments to assess the capabilities of insulated ice bunker railcars to maintain desired transit temperatures.

RAIL TRANSPORT IN EUROPE

Every western European country has its own national railroad which, in most cases, is state or quasistate operated. Throughout Europe there is a vast interlocking network of railroad systems which provides rail service from all major ports to all major food distribution centers.

Organization of Railroads

In 1949, six European railroads founded the Interfrigo organization, which performs a function similar to Fruit Growers Express and Pacific Fruit Express in the United States. The aim of Interfrigo is to provide the optimum utilization of the available stock of railcars for all controlled temperature 3/ transport of perishables and frozen products in international traffic. In 1976, there were 22 member railroads in the Interfrigo organization. The activities of Interfrigo cover practically all the continent of Europe and most of the Mediterranean area (fig. 1).

All international transport of controlled temperature shipments originating from a member railroad in Europe is assigned to Interfrigo. During 1975, Interfrigo carried over 253,000 loads of perishable products under controlled temperatures. About 75 percent of these loads were fresh fruits and vegetables, and the majority of these shipments was in insulated ice bunker railcars.

In member countries, Interfrigo is normally represented by the national railroad of the country. In some cases, Interfrigo is represented by subsidiaries of the national railroads or other companies; the main ones are STEF in France, Transthermos in the Federal Republic of Germany, Transfriebel in Belgium, Frigosuisse in Switzerland, and Transfesa in Spain.

As Interfrigo is not represented in the United States, it is recommended that U.S. shippers use a European forwarder or have the receiver arrange for the transport of their shipment within Europe. These forwarders provide such services as booking of the railcars, loading and closing of the railcars, determining and ordering the cooling or heating service in the railcars, weighing the load, preparing bills of lading, and handling customs formalities.

3/ Controlled temperature as used in this report does not necessarily mean that the temperature within the railcar is thermostatically controlled, but it includes all shipments in insulated ice bunkers and mechanically refrigerated railcars and van containers.

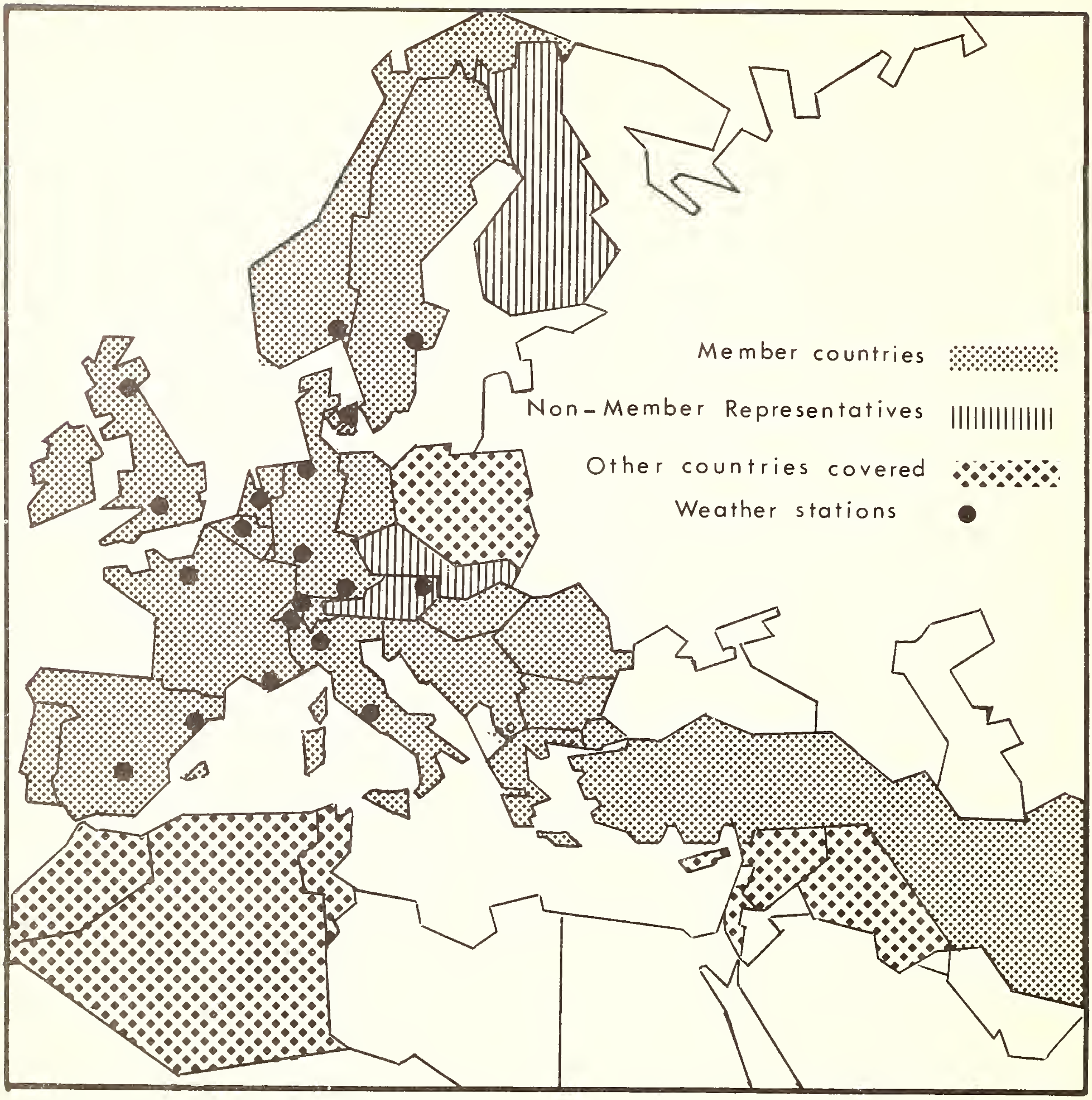


Figure 1.--Countries where Interfrigo operates rail transport, 1975. The maximum and minimum temperatures of these weather stations are shown in table 1.

Types of Equipment Available

In 1975, Interfrigo operated over 18,200 railcars belonging to its members and their affiliated companies. About 10,000 of these are noninsulated-ventilated railcars. 4/ In addition, Interfrigo owns about 7,600 insulated ice

4/ The noninsulated-ventilated railcar will not be described in this report because its use is not recommended for U.S. fresh fruits and vegetables.

bunker railcars, 1,567 mechanically refrigerated railcars, and 125 mechanically refrigerated 20- and 40-foot van containers. Interfrigo also supplies flat railcars for carrying van containers of other companies.

Insulated Ice Bunker Railcars

Interfrigo operates four general types of insulated ice bunker railcars that vary in size (table 2). All insulated ice bunker railcars have an ice bunker at each end of the railcar. Each railcar is equipped with four air circulators. The air circulators are located either in the roof (fig. 2A) or in each end of the railcar (fig. 2B). The air circulators mounted on the roof of the railcar are driven by outside air--so-called Flettner circulation. The air circulators located at the ends of the railcar are powered by a generator which is energized by the movement of the railcar axles. These air circulators may also be operated by connecting them to a standby or stationary power supply. No positive method of fresh air exchange is available; however, the ice bunker doors can be left open for the intake of fresh ambient air. Insulated ice bunker railcars are generally equipped with metallic, detachable floor racks. Some of the insulated railcars are also equipped with either fixed or detachable meat rails and hooks.

Cooling is provided by placing blocks of water ice or dry ice in the ice bunkers. Movable ice bunker walls are available in certain railcars with Flettner-type circulation.

Heating is provided by several types of portable, nonthermostatically controlled gas heaters. The heaters are generally placed directly on top of the load and rely on air circulation for distribution of the heat within the load. The heater most commonly used is a gas one which can be controlled at full, two-thirds, and one-third capacity (fig. 3).

When the railcar is ordered, the forwarder, receiver, or shipper must determine the cooling or heating requirements based on the projected transit weather forecast. Table 1 gives some indication of the average maximum and minimum temperatures by month for several cities in western Europe.

Mechanically Refrigerated Railcars

Mechanically refrigerated railcars are available for transport of fresh and frozen products. Some of these railcars are equipped with the thermostatic controls that can maintain temperatures from -25 to +20 ^{o}C, while others can maintain only certain temperatures (table 3). The refrigeration units are powered by diesel-driven generators or, when stationary or on a siding, they can be plugged into local electrical power supply. The characteristics of the Interfrigo-operated, mechanically refrigerated railcars are listed in table 3.

TABLE 1.--Monthly average maximum and minimum temperatures in ^{o}C for western European cities shown in figure 1

Country and city	Record period	January Max	January Min	February Max	February Min	March Max	March Min	April Max	April Min	May Max	May Min	June Max	June Min
Austria:													
Vienna	1931-60	8.9	-11.5	11.5	-9.9	17.5	-5.6	23.1	0.1	26.8	3.5	28.9	8.6
Belgium:													
Brussels	1957-66	10.5	-8.5	14.2	-5.8	18.2	-3.9	22.0	-.7	25.6	1.0	29.6	5.6
Denmark:													
Copenhagen	1931-60	7.2	-8.2	7.9	-8.2	11.4	-6.2	17.5	-1.6	23.7	2.5	26.3	6.5
France:													
Paris	1931-60	13.3	-5.8	15.1	-5.2	20.5	-1.4	24.3	1.4	27.4	4.5	31.1	8.2
Marseilles	1931-60	15.5	-5.4	17.6	-4.9	19.8	-2.8	22.8	.7	27.4	4.8	31.3	9.0
Germany:													
Bremen	1931-60	9.8	-10.3	10.7	-10.7	16.4	-6.2	21.6	-2.1	26.4	1.1	29.3	4.8
Frankfort on the Main	1931-60	10.3	-9.6	11.6	-8.5	19.2	-4.1	24.3	0.0	28.7	2.6	31.4	7.4
Munich	1931-60	10.6	-15.5	12.1	-14.8	18.2	-8.7	22.6	-3.5	26.3	.9	29.0	5.3
Italy:													
Rome	1953-68	15.7	-1.4	17.1	-.4	19.9	1.5	23.6	4.9	28.9	8.2	32.8	12.8
Milan	1953-68	11.2	-5.3	14.4	-2.6	19.5	.8	24.3	4.6	28.8	8.4	32.0	12.0
Netherlands:													
De Bilt	1931-60	10.5	-9.0	11.7	-8.3	17.5	-5.2	21.0	-1.4	26.3	.9	29.2	4.2
Norway:													
Oslo	1931-60	5.7	-16.5	6.6	-15.6	11.1	-11.8	17.0	-5.3	23.7	0.0	27.1	4.5
Spain:													
Barcelona	1934-60	18.1	1.2	18.4	1.9	20.6	4.2	23.5	7.4	26.8	9.5	30.4	14.2
Madrid	1934-60	14.2	-4.4	16.9	-3.2	21.6	0.0	25.1	2.4	28.5	4.4	33.4	9.2
Sweden:													
Stockholm	1931-60	5.1	-13.9	4.9	-13.1	9.7	-10.7	15.8	-4.7	22.2	.5	26.0	5.7
Switzerland:													
Zurich	1931-60	10.2	-9.9	13.1	-9.3	19.0	-5.3	23.7	-1.4	27.5	2.2	30.5	6.9
Geneva	1931-60	11.5	-7.8	12.7	-7.8	18.1	-3.7	22.2	-.1	26.4	3.0	30.1	7.3
United Kingdom:													
Oxford	1931-60	12.1	-5.7	13.2	-4.8	17.0	-3.5	20.4	-.6	24.3	1.3	26.9	5.7
Edinburgh	1931-60	11.1	-4.2	11.4	-3.9	14.1	-2.4	16.9	-.4	20.3	1.4	23.5	5.4

TABLE 1.--Monthly average maximum and minimum temperatures in ^{o}C for western European cities shown in figure 1--Continued

Country and city	Record period	July Max	July Min	August Max	August Min	September Max	September Min	October Max	October Min	November Max	November Min	December Max	December Min
Austria:													
Vienna	1931-60	31.4	11.3	30.4	10.4	27.2	5.8	21.4	0.4	14.3	-3.0	11.3	-8.4
Belgium:													
Brussels	1957-66	31.0	6.8	29.9	6.8	28.2	5.2	22.5	1.9	15.6	-2.8	12.1	-6.9
Denmark:													
Copenhagen	1931-60	27.3	9.7	26.4	9.1	22.5	4.9	16.7	1.0	11.3	-1.8	8.7	-5.3
France:													
Paris	1931-60	33.2	10.6	31.1	9.6	28.6	7.1	23.9	1.4	16.5	-1.7	13.3	-3.8
Marseilles	1931-60	33.7	11.9	33.0	11.1	29.8	7.4	25.2	1.4	19.9	-1.9	16.9	-4.0
Germany:													
Bremen	1931-60	30.5	7.9	29.8	7.4	25.9	3.4	19.2	-1.3	13.6	-3.6	10.9	-8.1
Frankfort on the Main	1931-60	32.7	10.1	32.2	9.1	28.3	4.7	21.1	.1	14.5	-2.5	10.5	-7.4
Munich	1931-60	30.8	7.9	30.6	6.9	27.2	2.6	21.6	-2.3	14.8	-5.8	11.6	-12.4
Italy:													
Rome	1953-68	34.6	15.8	34.2	16.0	30.2	12.7	25.9	7.2	21.2	2.8	17.0	.7
Milan	1953-68	33.6	14.7	32.6	14.5	28.8	11.1	23.1	5.6	15.4	1.4	12.5	-3.8
Netherlands:													
De Bilt	1931-60	29.9	7.4	28.9	7.0	26.0	4.0	19.5	-.5	14.2	-3.1	11.5	-7.2
Norway:													
Oslo	1931-60	28.2	8.0	26.5	6.8	21.0	1.1	16.0	-3.1	9.5	-8.5	6.8	-13.6
Spain:													
Barcelona	1934-60	32.2	17.7	32.1	17.1	29.1	14.3	24.7	8.6	21.2	6.1	17.6	2.7
Madrid	1934-60	36.2	12.3	35.2	12.4	31.3	8.3	24.1	3.2	17.6	0.0	14.0	-2.2
Sweden:													
Stockholm	1931-60	27.8	10.5	26.0	8.9	20.7	3.5	14.8	-1.3	9.4	-5.5	6.7	-9.3
Switzerland:													
Zurich	1931-60	32.1	9.3	31.3	8.7	27.5	4.7	21.6	.1	14.5	-3.2	11.2	-7.4
Geneva	1931-60	31.9	9.4	31.2	9.3	27.2	5.8	21.3	.8	14.6	-2.5	12.2	-5.9
United Kingdom:													
Oxford	1931-60	27.9	7.8	27.5	7.3	24.6	3.8	19.3	-.7	14.9	-2.4	12.6	-4.5
Edinburgh	1931-60	23.7	8.0	23.0	7.3	20.7	4.7	17.1	1.2	13.5	-.3	11.9	-3.0

Source: Royal Dutch Meteorological Institute, The Netherlands.

TABLE 2.--Principal characteristics of various insulated ice bunker railcars operated by Interfrigo, 1975 1/

Physical characteristic	2-axle railcar, standard	2-axle railcar, large capacity		2-axle railcar, very large capacity		4-axle railcar, bogie high capacity	
		Type A	Type B	Type A	Type B	Type A	Type B
Payload, tons 2/	13.5-15.5	15.1-19.1	17.6-25.6	17.0-25.0	16.5-20.5	36.6-44.6	34.9-50.9
Inside dimensions:							
Length, meters 3/	7.6	8.5	10.5	10.6	10.6	15.4	16.7
Width, meters 3/	2.5	2.5	2.2	2.6	2.6	2.6	2.5
Height, meters 3/	1.9	1.8	1.8	2.0	1.8	1.8	1.9
Floor surface, square meters 4/	19.5	22.0	23.6	27.7	27.5	40.0	42.5
Cubic volume, cubic meters 5/	39.0	41.0	43.9	56.0	51.0	76.0	84.0
Loading capacity, number of pallets 6/	14.0	14.0	16.0	20.0	20.0	30.0	32.0
Ice bunker capacity, tons 2/	2.7	3.6	3.8	4.8	4.8	6.9	7.0

1/ Data supplied by Interfrigo, Basel, Switzerland.
2/ 1 ton equals 2,205 pounds. The payload of each type of railcar depends on the speed of the train and the destination country.
3/ 1 meter equals 3.28 feet and is rounded to the lowest tenth.
4/ 1 square meter equals 10.76 square feet.
5/ 1 cubic meter equals 35.31 cubic feet.
6/ Standard European pallet size is 1000 by 1200 millimeters; this is about equal to a 40- by 48-inch pallet used in the United States.

TABLE 3.--Principal characteristics of various mechanically refrigerated railcars operated by Interfrigo, 1975 1/

Physical characteristic	2-axle railcar		4-axle bogie railcar		
	Standard	Special	Standard	Special 1	Special 2
Payload, tons 2/	16.0-24.0	15.5-23.5	31.4-47.4	33.0-41.0	29.0-37.0
Inside dimensions:					
Length, meters 3/	11.4	9.9	17.7	16.5	16.2
Width, meters 3/	2.5	2.5	2.5	2.5	2.3
Height, meters 3/	2.0	2.0	1.9	1.9	1.9
Floor surface, square meters 4/	29.0	25.0	45.0	43.0	37.0
Cubic volume, cubic meters 5/	58.0	50.0	89.0	84.0	70.0
Loading capacity, number of pallets 6/	22.0	18.0	34.0	30.0	24.0
Refrigeration temperature range, °C	-25 to +20	-25 or + 2 7/	-25 to +20	-25 or + 2 7/	-20
Heating possibilities	Yes	No	Yes	No	Yes
Number of days railcar can operate with full tank	7-9	7-9	13	10	8
Air distribution ducts	Yes	No	Yes	No	No

1/ Data supplied by Interfrigo, Basel, Switzerland.

2/ 1 ton equals 2,205 pounds. The payload of each type of railcar depends on the speed of the train and the destination country.

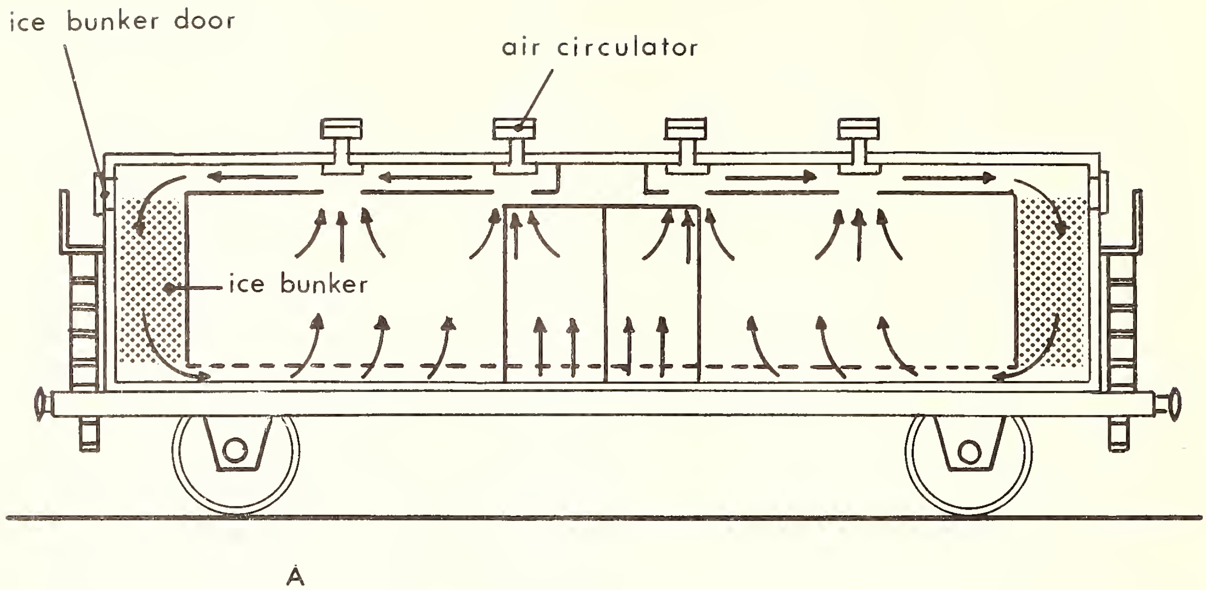
3/ 1 meter equals 3.28 feet and is rounded to the lowest tenth.

4/ 1 square meter equals 10.76 square feet.

5/ 1 cubic meter equals 35.31 cubic feet.

6/ A standard European pallet size is 1000 by 1200 millimeters; this is about equal to a 40- by 48-inch pallet used in the United States.

7/ On this type of railcar, the thermostats can be set at only 2 positions, generally -25 and +2 °C, but they can be changed to other settings by the representatives of Interfrigo.



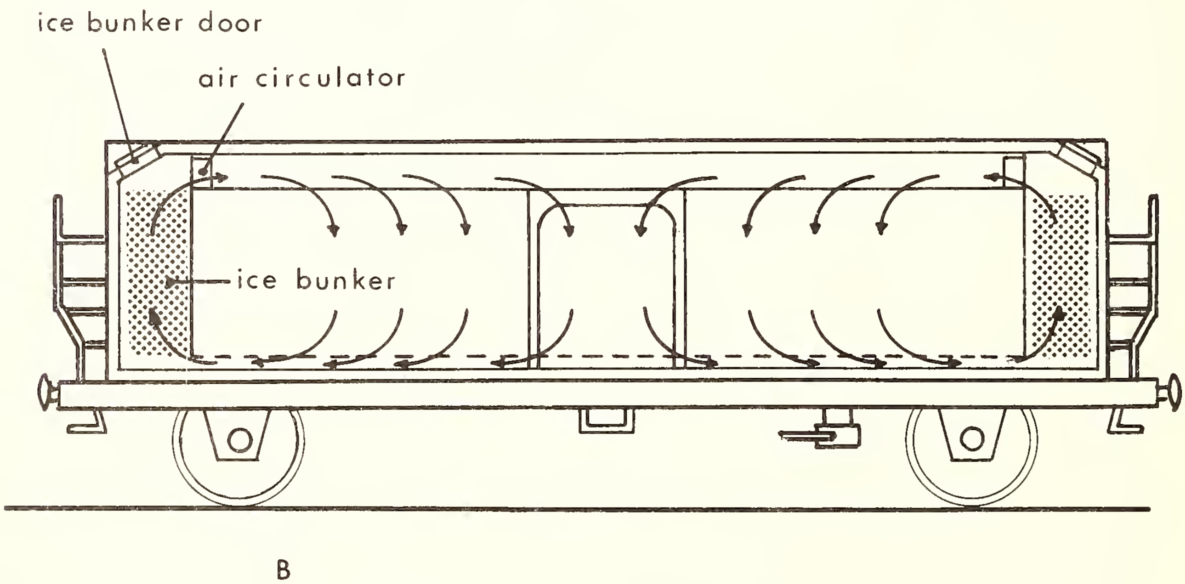


Figure 2.--Cross-sectional view of two types of insulated ice bunker railcars: A, Railcar equipped with Flettner air circulators; B, railcar equipped with electrical air circulators.

Mechanically Refrigerated Van Containers

The Interfrigo organization owns a number of 20- and 40-foot mechanically refrigerated van containers. The temperature in the van containers is thermostatically controlled and temperatures can be maintained from -25 to +15 °C. The refrigeration units are powered by diesel-driven generators or, when

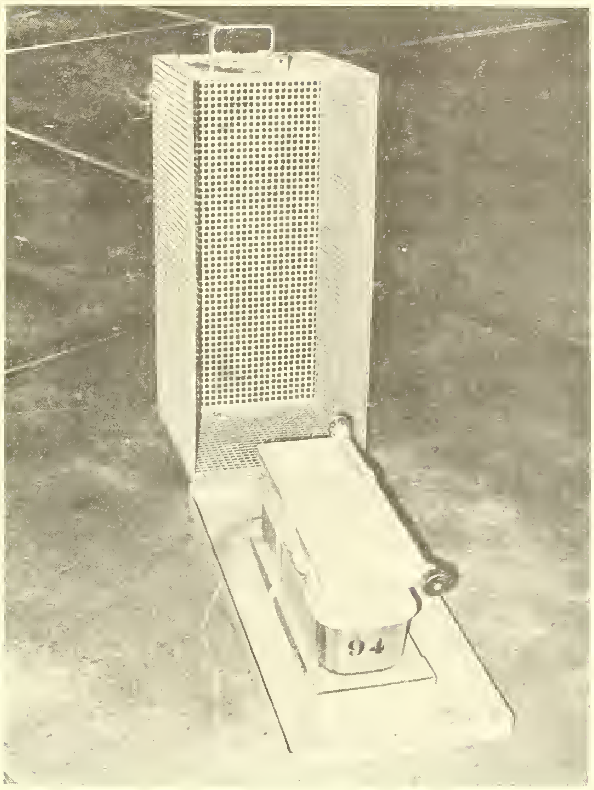


Figure 3.--Gas heater used for heating. It usually is placed on top of the load.

stationary or on a siding, they can be operated on local electrical power supply. The van containers conform to the International Standardization Organization's standards.

TEST SHIPMENTS

The time in transit from the port area to the major European distribution centers is up to 5 days. Maintenance of optimum temperatures during this period can reduce spoilage and extend the shelf life of perishable products. Protecting the commodity from temperature extremes and drastic temperature changes during transit is also an important requirement. For instance, transit without protection during March from Bremen, with average minimum temperatures below 0 ^{o}C, to Madrid, with maximum temperature of 21 ^{o}C, could mean the difference between receiving a marketable product and not.

Some U.S. products will be arriving in Europe near the end of their market life, and maintenance of desired transit temperature will be necessary to provide the retailer and consumer with a quality product. So it is important that the rail equipment be able to maintain the recommended temperatures during transit.

For this series of tests, insulated ice bunker railcars were used, as this type of railcar can maintain recommended transit temperatures and the supply is more plentiful than mechanically refrigerated railcars. The product used was bananas because of their specific temperature requirements and their availability for tests. The desired transit temperature for green bananas is 13.5 to 14.5 °C (56 to 58 °F). Transit temperatures higher than 14.5 °C cause ripening and temperatures much below cause chilling injury to certain varieties. Large differences in temperatures during transit result in uneven ripening and marketing difficulties.

A total of eight test shipments were made during 1973 and 1974. The description and result of each shipment are shown in table 4. However, only three shipments (1, 2, and 3) will be discussed in detail. The three shipments were made in August and September 1973 and January 1974 from Rotterdam, The Netherlands, to destinations in Switzerland. These shipments were selected as representative of a summer shipment, where water ice was used for cooling; a fall-spring shipment, where only air circulation was used; and a winter shipment, where a gas heater was used for heating. For all three shipments, a large-capacity, insulated ice bunker railcar with electrical air circulators was used (as shown in figure 2B).

The bananas for each shipment were loaded directly from the ship into the railcar. At loading, the bananas were hard green. Banana boxes were loaded in register, one box directly on top of another, as shown in figure 4.

Figure 4.--Inside view of insulated ice bunker railcar shows the method of loading banana cartons and electrical fans used for air circulation.

TABLE 4.--Description of shipment and average temperatures for 8 shipments by insulated ice bunker railcars from Rotterdam, The Netherlands, to Switzerland, 1973-74

Shipment and date	Hours in transit	Number of boxes per railcar	Amount of ice or stove capacity	Pulp temperatures at loading		Ambient temperatures during transit		Pulp temperatures upon arrival	
				Highest	Lowest	Highest	Lowest	Highest	Lowest
				°C	°C	°C	°C	°C	°C
1--August 1973	49	650	500 kg water ice	14.4	13.9	30.0	15.6	16.7	14.4
2--January 1974	45	500	Gas heater 2/3 capacity	15.6	12.2	9.4	1.1	19.4	14.4
3--September 1973	52	600	Only air circulation	16.7	13.9	27.8	12.8	17.8	16.1
4--August 1973	47	800	500 kg water ice	15.0	14.0	28.3	12.2	19.5	12.7
5--January 1974	35	550	Gas heater 1/3 capacity	14.4	11.1	8.3	4.4	16.1	11.7
6--February 1974	47	730	Gas heater 2/3 capacity	13.9	12.2	8.9	0.0	20.0	12.8
7--June 1974	46	600	400 kg water ice	15.6	14.4	28.3	11.7	18.3	13.9
8--August 1974	42	800	500 kg water ice	15.6	14.4	30.6	14.4	17.2	12.7

In the summer shipment, with water ice in the ice bunker for cooling, sheets of corrugated fiberboard were used as insulation between the interior walls and the loading area of the railcar. During the winter shipment with a gas heater on top of the load for heating, sheets of corrugated fiberboard were used as insulation between the interior walls of the railcar and loading area and on top of the floor grating (fig. 5). Sheets of corrugated fiberboard were not used for insulation in the fall-spring shipment where neither water ice nor a gas heater was used. In the summer shipment 500 kilograms (1,100 pounds) of water ice was used, half in each ice bunker in each end of the railcar. In the winter shipment, a gas heater (as shown in figure 3) was used at two-thirds capacity. As previously stated, the amount of water ice and the setting of the heater were determined by the receiver based on the projected weather forecast for the transit period.

Thermistor-type probes attached to a battery-operated recorder were used to record temperatures hourly during transit. In each shipment, 19 probes were used to monitor product temperatures and 7 probes were used to monitor air temperatures. The location of these probes is shown in figure 6.

RESULTS AND DISCUSSION

Average product temperature at loading ranged from 13.9 to 14.4 $^{\circ}$C and from 15.0 to 16.7 $^{\circ}$C at unloading for the three shipments selected for detailed study. There was little variation in product temperature during transit except for the winter shipment.

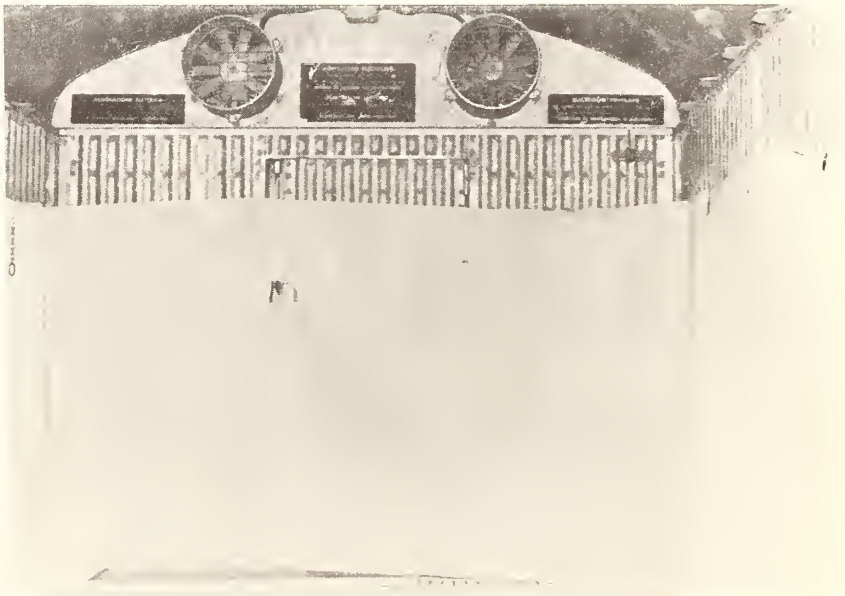


Figure 5.--Inside view of insulated ice bunker railcar before loading shows electrical fans and sheets of corrugated fiberboard, used during the winter shipment for insulation, on interior walls and floor of railcar. During the summer shipment, insulation material is only placed against ice bunker walls at each end of railcar.

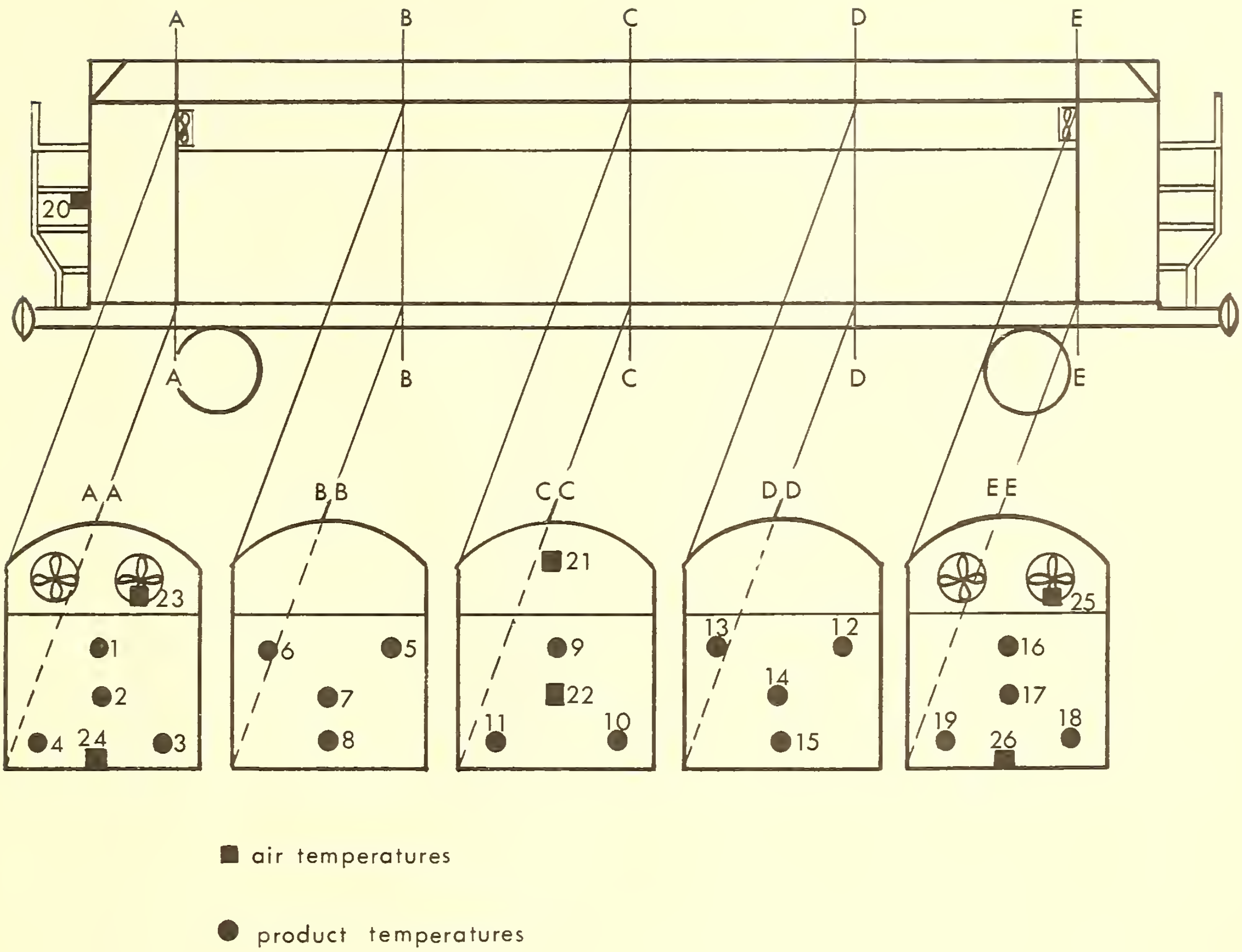


Figure 6.--Location of temperature probes (1-26) within insulated ice bunker railcars to monitor product and air temperatures in banana shipments.

The range of product temperatures for the summer shipment at unloading and during most of the transit period was between 13.9 and 16.7 °C (fig. 7). Ambient air temperatures during transit ranged from 15.6 to 30.0 °C. In figure 7, note that the temperature of the air above the load varies with the ambient air temperature, but this does not greatly affect the temperature of the product. Also in figure 7, the temperature of the return air (temperature of the air directly below the ice in the airspace of the floor racks under the ice bunker) varies with the movement of the railcar. When the railcar is moving and the fans operating, the temperature of the return air corresponds to the product temperature. When the railcar is not moving and the fans not operating, the temperature of the return air decreases because the cold air settles downward in the ice bunker.

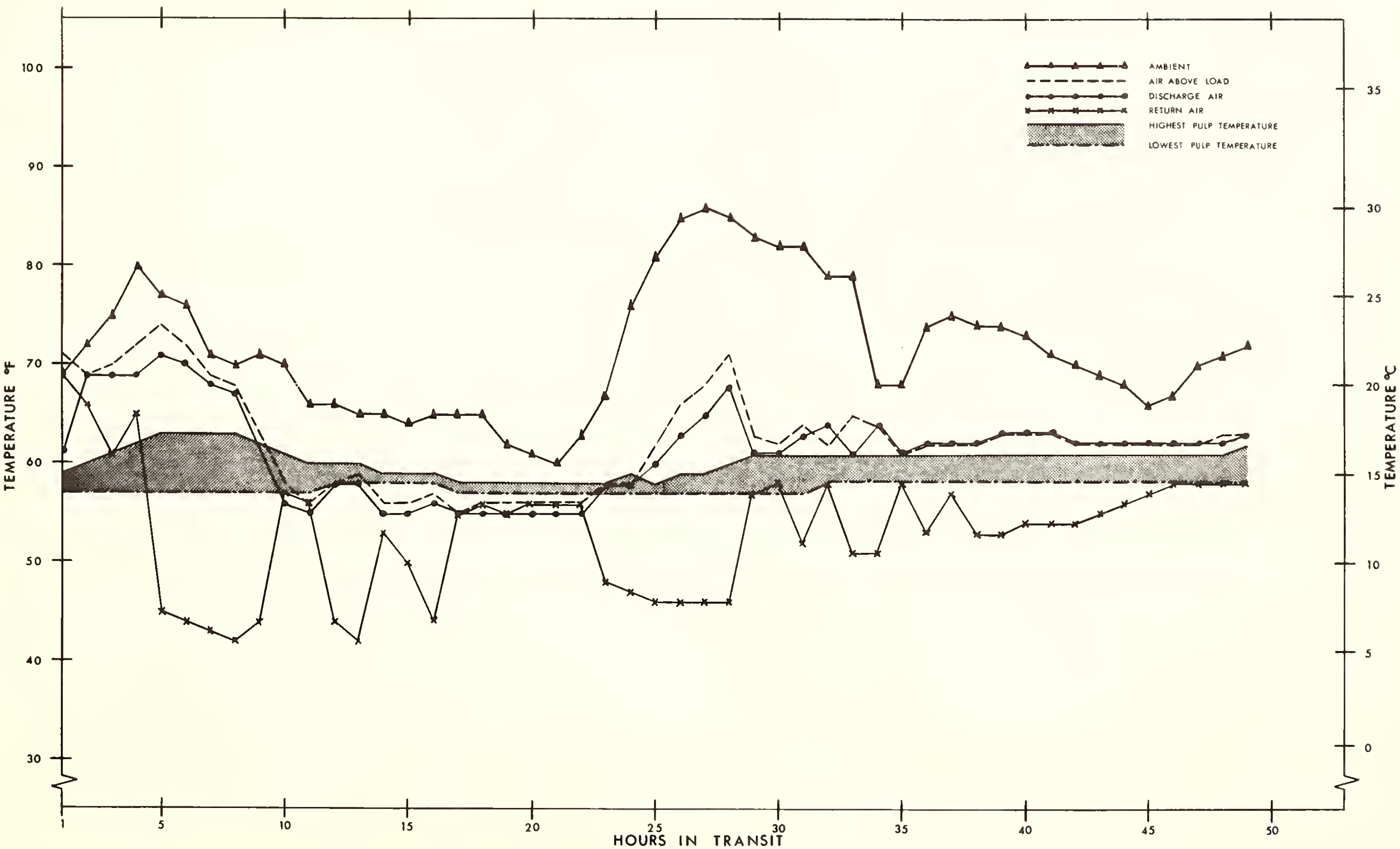


Figure 7.--Product and air temperatures of summer shipment of bananas using water ice in an insulated ice bunker railcar from Rotterdam, The Netherlands, to San Antonio, Switzerland, August 1973.

The range of product temperatures for the winter shipment at unloading was between 14.4 and 19.4 ^{o}C (fig. 8). The ambient air temperature during transit ranged from 1.1 to 9.4 ^{o}C, indicating that the gas heater and insulation of the railcar efficiently maintained the product temperature. In figure 8, the discharge air temperature and the temperature of the air above the load again relates to movement of the railcar and operation of the fans. When the railcar is moving, the temperature of the discharge air and the air above the load is nearer to the product temperature; when the railcar is not moving, the temperature of the discharge air and air above the load increases. Generally, the spread in product temperatures was largest during winter shipments. The highest product temperatures were in the top-layer boxes, caused in part by the gas heater being placed on top of the load. The product temperatures of the top-layer boxes averaged 2 ^{o}C higher than the product temperatures of the bottom-layer boxes.

The range of product temperatures for the fall-spring shipment at unloading was 16.1 to 17.8 ^{o}C (fig. 9). The spread in product temperatures throughout the shipment was the smallest of any shipment, even though ambient air temperature reached 27.8 ^{o}C for a few hours just before unloading.

RECOMMENDATIONS AND CONCLUSIONS

The results of the three test shipments indicate that insulated ice bunker railcars were fairly effective in maintaining product temperatures at various times during the year. The transit period is relatively short, and ambient air temperatures are fairly moderate. Generally, during winter months when gas heaters are used for heating, there is more spread in product temperatures upon arrival.

Based upon these shipments, several recommendations can be made. One of the recommendations is to suspend the gas or catalytic heaters from hooks on the ceiling or to place them in the ice bunkers. This should decrease the spread in product temperatures during winter shipments because the heaters would not be in direct contact with the product. The second recommendation is to find some way to supply continuous power to the air circulation fans, so the fans would continue to operate when the railcar is not moving. In some shipments it was noted that boxes of product were stacked higher than the fans, thus blocking air circulation. A third recommendation is that boxes be so stacked that air circulation is not blocked within the railcar.

In general, insulated ice bunker railcars can be used for certain U.S. agricultural products which require transit temperatures between 5 and 16 ^{o}C (40-60 ^{o}F). It must be remembered that when fresh fruits and vegetables are shipped from the United States to Europe, the product's shelf life has nearly been exhausted during the inland transit within the United States and the ocean transit. Therefore, the transit time within Europe should be relatively short and at the desired transit temperature of the product. The use of insulated ice bunker railcars should be acceptable for such products as citrus fruits, onions, potatoes, etc. Depending upon the ambient air temperatures during the transit period within Europe, the shipper, forwarder, or receiver must decide whether water ice is needed for cooling or gas heaters are needed for heating.

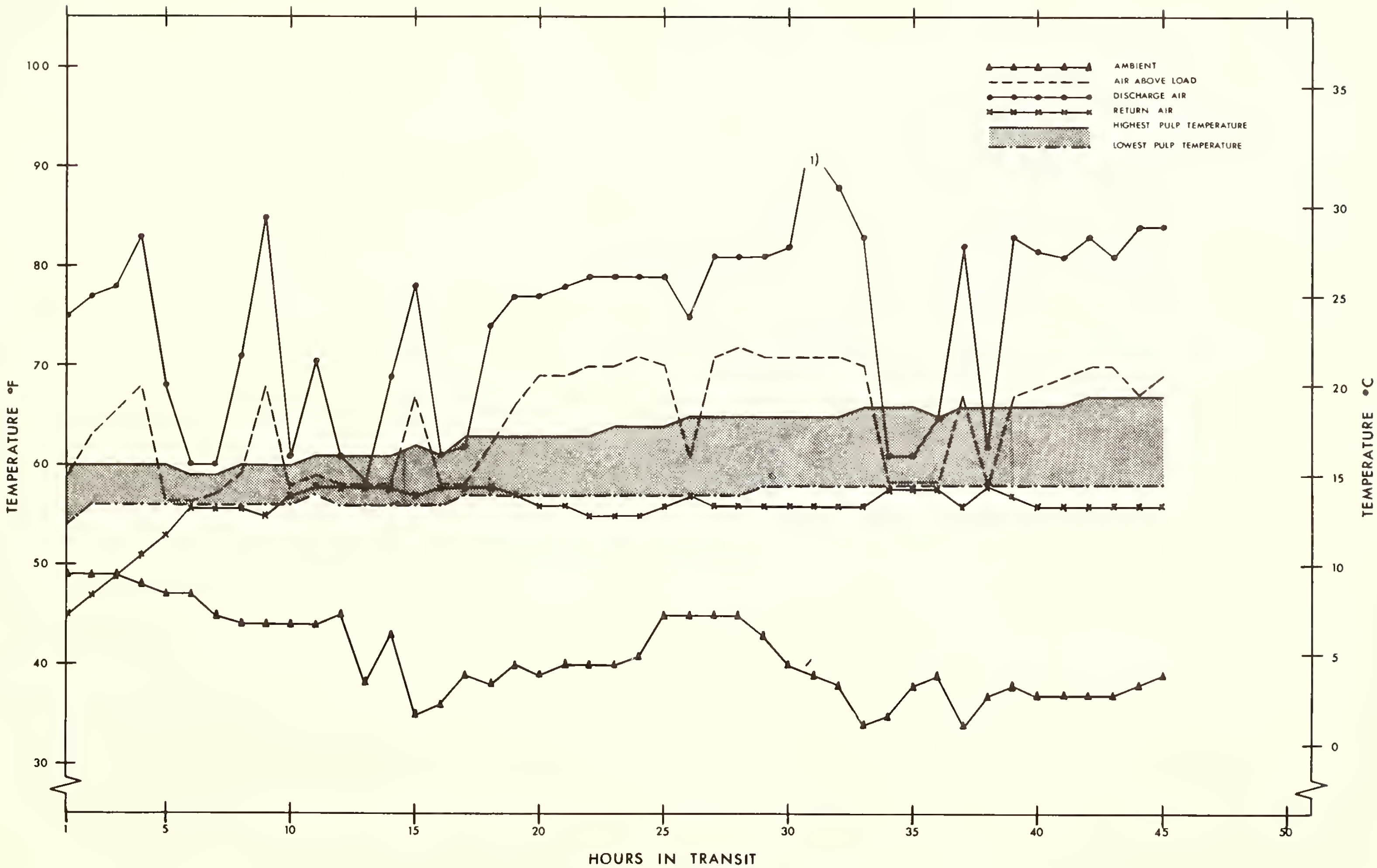


Figure 8.--Product and air temperatures of winter shipment of bananas using a gas heater in an insulated ice bunker railcar from Rotterdam, The Netherlands, to Locarno, Switzerland, January 1974. [1) This indicates that temperature was above 32.2 °C, the limit of the temperature recorder used for the tests.]

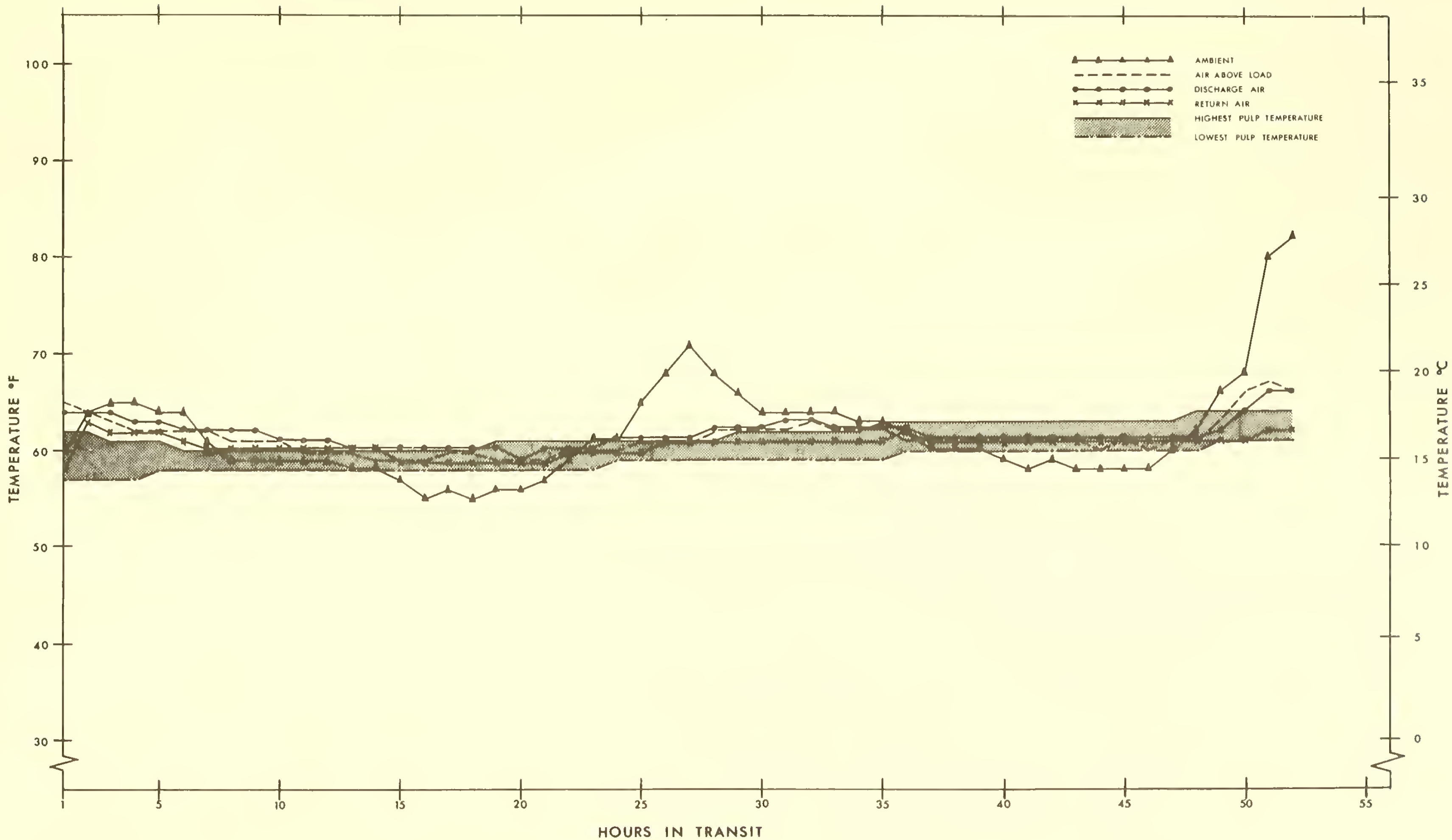


Figure 9.--Product and air temperatures of fall-spring shipment of bananas using only air circulation in an insulated ice bunker railcar from Rotterdam, The Netherlands, to Zurich, Switzerland, September 1973.

For other fresh fruits and vegetables requiring temperatures nearer to the freezing point, mechanically refrigerated railcars or trucks are recommended. Refrigeration is generally not provided in most truck movements of fresh fruits and vegetables within Europe unless specifically requested. If shipments from the United States are by refrigerated van containers, it is suggested that this same van container be used for inland European transit, either on a truck or a rail flatcar.

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